



# Stanford Today

WINTER 1963

THE MULTIVATOR: *Martian Life Detector*

# Stanford Today

WINTER 1963

MAN IS LOOKING to other planets for the answer to the most fundamental and perplexing research problem of all: how did life begin? Stanford geneticists and engineers are working together on one part of the search. They are experimenting with a life detection instrument which, landed 50 million miles away on Mars, could radio back evidence of microbial existence.

*In LIFE BEYOND THE EARTH  
Joshua Lederberg tells of the new science,  
exobiology. He pioneered the field  
and gave it its name.*

*PAYLOAD TO MARS sets the matrix for  
space life missions. Elliott Levinthal—physicist  
who has become something of a chemist  
and biologist as well—is the author.*

*THE MULTIVATOR (shown on the cover)  
is one choice of a detection system being  
developed in Stanford laboratories.*

## STANFORD TODAY

Second class postage paid at Palo Alto, California. Issued four times a year, in March, June, September, and December.

SERIES 1, No. 7      DECEMBER 1963

STANFORD TODAY is produced quarterly by the Publications Service of Stanford University.  
*Editor:* Peter C. Allen, '36 • *Assistant Editor:* Ralph P. Handy, '51 • *Design:* Walter C. Peterson, '38 • *Photography:* José Mercado

### *Faculty Editorial Advisory Committee*

David Levin, *Chairman* • Don E. Fehrenbacher • Albert H. Hastorf • Joseph P. Kriss, M.D. • Robert McKim • Arthur L. Schawlow • Leon E. Seltzer • Patrick C. Suppes  
Sharon S. Cobb, *student member*

© 1963 by the Board of Trustees of The Leland Stanford Junior University. Permission to reprint any part of *Stanford Today* must be obtained in writing from the editor. Please address any correspondence regarding this publication to STANFORD TODAY, STANFORD, CALIFORNIA. When notifying of address change, please clip and enclose the address panel from back cover.

# LIFE BEYOND THE EARTH

by JOSHUA LEDERBERG

**T**O THE HISTORIAN looking backward from future time, this century will be memorable for a number of peaks in the evolution of human culture: the concentration of national power in global conflict, the shrinking of the globe by air transport and wireless communication, the exploitation of nuclear energy, the technological revolution of computers and automation, the reunification of the sciences, the unraveling of the physical mechanism of life. All of these movements have a common focus in the exploration of space, the millionfold extension of human activity from the earth's crust to the reaches of the solar system. The same power and resources that can count down the survival of civilized man can also light his noblest aims.

What do we seek in space? Not astronomical

numbers. Emptiness multiplied is at most very little. The journey does give us two unique rewards: a perspective on our own planet and a prospect on other worlds. The first pioneering steps in space—the orbiting satellites that can analyze our atmosphere, show our weather, speed communications, help navigation, or warn of global dangers—are already doing their useful tasks and begin to show their merits in advancing scientific knowledge of the earth. Now, as our vehicles become more powerful, we must measure our reach and attend to our objectives in exploring the other celestial bodies. Among these objectives, the study of life beyond the earth, which we term “exobiology,” is the most subtle and demanding, for it insists: “Know thyself.”



BIOLOGY has experienced an amazing development as a scientific discipline, particularly in the biochemical understanding of the mechanism of life. But its domain has been limited to the thin shell of our own planet, to the way in which one spark of life has illuminated one speck in the cosmos. By contrast, the basic laws of physics are derived from the motion of the stars, and we know the scope of chemistry from spectral analysis of the light emitted by stars and galaxies at the boundaries of the observable universe. Biology has no such grand system. There is perhaps only one principle which we can confidently expect to have universal application. This is Darwin's principle of evolution, the magnificent process which explains how the complexity of amoeba or the grandeur of *Sequoia sempervirens* could have materialized.

The evolution of life on Earth, we now know, occurred in three stages:

*Chemogeny*, the production of complex organic compounds by a variety of nonreplicative mechanisms—the primitive aggregation of matter, photochemistry of isolated atmospheres, thermal, inorganic-catalyzed, and spontaneous reactions of previously formed reagents.

*Biogeny*, the replication of a specifically ordered polymer (DNA) which specifies the sequence of its own replicates, and of RNA and proteins, from which cells and organisms are fashioned. Random error in replication and natural selection of the consequences result in the panoply of terrestrial life.

*Cognogeny*, the evolution of the mechanisms of perception, computation, and symbolic expression, which are the unique conditions for interpersonal communication, so that, from this, tradition can accumulate.

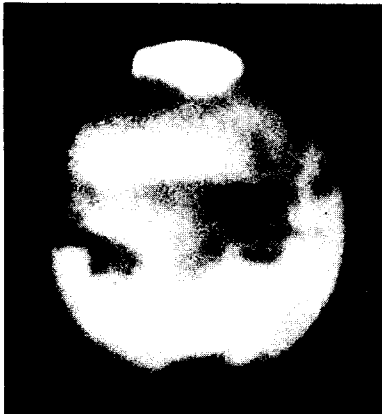
Despite their outward variety, the central components of all organisms are the same: their genetic material consists of nucleic acids, most of their structure consists of proteins. We are beginning to understand how the chemical properties of these substances underlie their function in the cell. But all cells have the same general composition. The boiled-down residues of the beef muscle would be hard to tell from the mushroom sauce; the nucleus of the human nerve cell from the virus that might attack it.

The conception of the central unity of terrestrial life has quickened the search for the origins of life. If we knew how specific proteins and

nucleic acids first appeared on the earth, we would have most of what we need to understand the further development of life. In the world now, proteins and nucleic acids are produced only as manifestations of life, as copies of what had evolved before. But how did this come about spontaneously, without pre-existing cell or brain to guide it? Thirty years ago this was regarded by some as a problem that might never be solved, as something beyond the reach of science. Today it leads to fundamental questions of exobiology. Are nucleic acids the only substances that can function in any heredity, or are they merely the ones that the path of earthly life has encountered? Are proteins, chains of just 20 amino acids, the only way of building up cell structures, or the accidental result of early chemical evolution on earth?

These questions might be answered in two ways. Presumptuous man might mimic primitive life by imitating Nature, furnishing substitute compounds. More humbly, he might ask Nature the outcome of its own experiments at life, as they might be manifest on other globes in the solar system.

OF ALL the planetary conditions, the abundance of water may be the most pertinent condition for the distribution of life as it is on Earth. All living cells contain far more water than any other component. Water plays many roles in the economy of the cell, but above all it is the indispensable solvent. The intricate work of the cell requires the ready intermingling of many kinds of molecules. This could only occur in solution, and, if not in water, the only obvious alternative, and only at very low temperatures, is ammonia or a similar liquefiable gas. Many other substances are vitally important to our own existence—for example, the oxygen in the air we breathe. But our own dependence on air should not exaggerate the generality of its importance. The vegetable kingdom and many simpler animals can survive without an external supply of oxygen, and even quite complex forms of life should be able to thrive without it, though they might replace the more efficient burning of foodstuffs with fermentation. Poisonous gases, like formaldehyde or carbon monoxide, in a planetary atmosphere might preclude human life, but man is not the measure of all things.



AUGUST 10

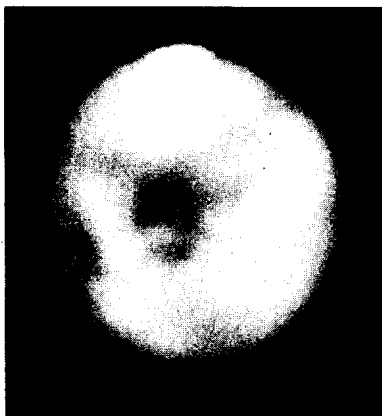
ORANGE



AUGUST 22

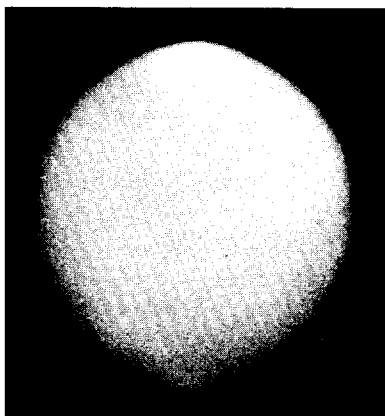
RED

Showing opposite hemispheres



SEPTEMBER 11

ORANGE



SEPTEMBER 11

BLUE

MARS IN 1956—Photographic images of Mars taken in different months with 60-inch Mt. Wilson telescope filtered to show the planet in red, orange, and blue light. The atmospheric haze in September has obscured much of the detail visible in August. Little but the polar cap, shown uppermost in each image, is visible in the blue light. (*California Institute of Technology—Mt. Wilson Observatory photograph*)

**T**HE MOON, Venus, Mars, and Jupiter are the celestial bodies nearest Earth and almost certainly will be on the itinerary of spacecraft in the decade ahead. Mercury is too close to the sun and Saturn, Uranus, Neptune, and Pluto too far from it to be on any early timetable.

The moon is handiest, but we are already positive that it is not quite large enough for its gravity to hold an atmosphere, and any free water on the surface would long since have evaporated into space. Some of these atoms will even have distilled over to the earth. We should still expect some traces of ice on the moon—condensed in sunless crevices—but these cold spots make it even more certain that the surface has no water, as it has no air, no weather of any kind, no present life. The moon thus is a marvelous relic on which to trace the primeval formation of the solar system. Its features have not been subjected to the continual metamorphosis we see on

weather-beaten Earth, and it is a target for the relentless impact of meteorites, particles ranging in size from single atoms to small planetoids orbiting in space until they happen to collide with the moon or a planet or are drawn into the sun. These meteorites have rained on its surface for a billion years unhindered by the atmosphere that fires their passage to the earth. The fossil moon therefore has its own sediments, a timeless record of cosmic history in the accumulated deposits of these materials collected from interplanetary space.

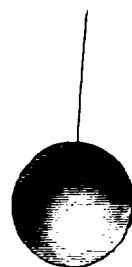
It would be of exceptional interest for cosmic biology to know whether meteorites can bridge the void from one planet to another. The moon's surface is almost the only place where we might find direct evidence of such an outflow from the earth. If the traces can be proven on the moon, we then could calculate that all the planets had interchanged fragments, perhaps even planetary systems of one star with another. This interchange would be much less than between the earth and its moon, and we might have no hope of finding direct evidence of it. But the arrival, just once in geological time, of a single fragment bearing a living spore would have immense potentialities for the future of a planet. The original purity of the moon's surface is thus an important scientific asset that should be conserved until we can plan our search for earthly traces on it.

**T**HE BRILLIANCE of Venus in our sky is due not only to its relative nearness and largeness, but also to the high reflectivity of layers of clouds which completely envelop it and which have, so far, prevented astronomers from seeing any of its surface details. Scientists had speculated that the surface might be relatively dark and cold, despite the closeness of the sun, because of the cloud shield. Now it is known that the surface is hot, attributable to the "greenhouse effect" of the high content of carbon dioxide in the atmosphere. Measurements by radiation methods indicate a surface temperature of about 400° F., and data gathered in the 1962 Mariner fly-by may raise this estimate beyond 600° F.—a



PLUTO

4000 / 1



NEPTUNE

2800 / 4

sizzling oven in which neither liquid water nor typical organic molecules could long survive.

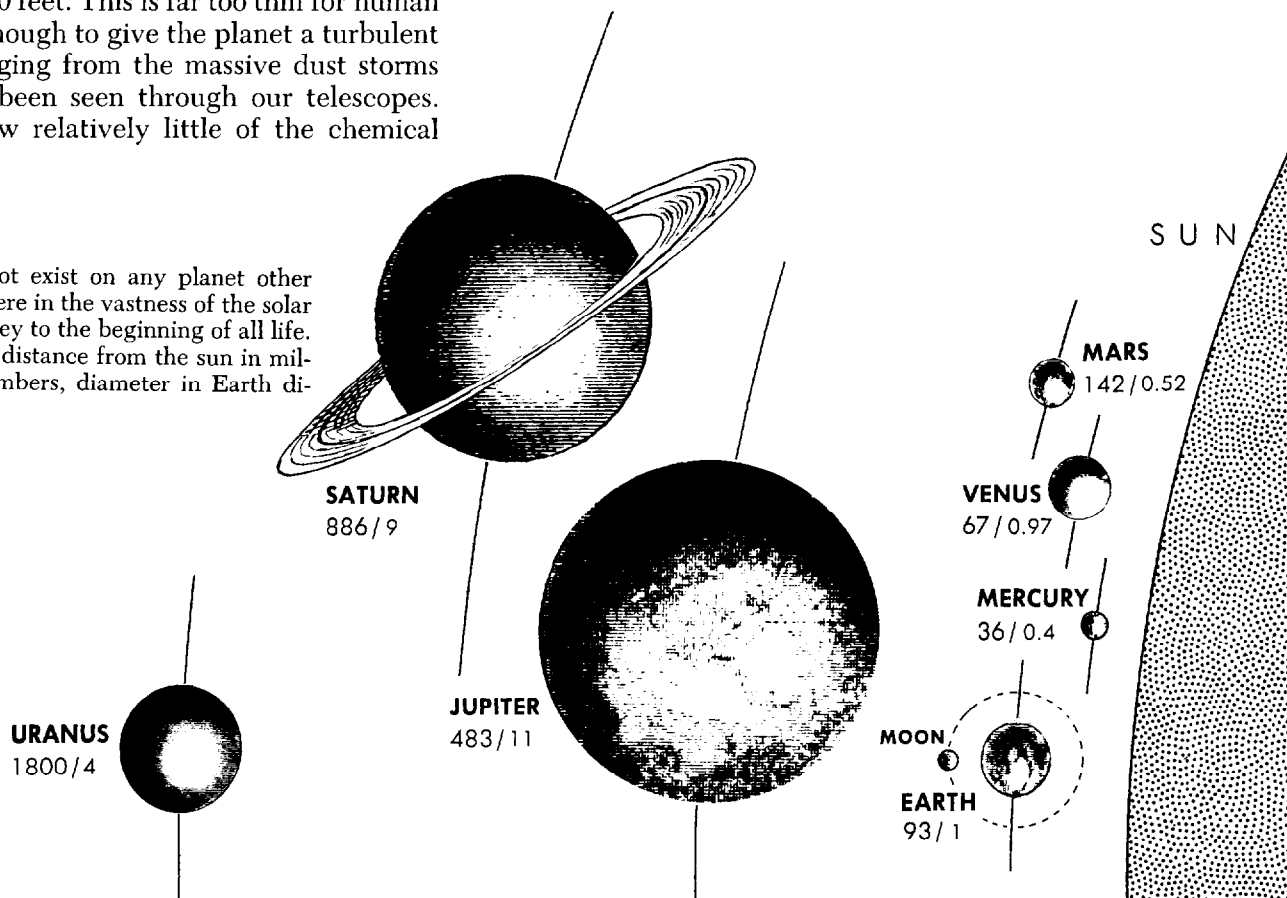
If these measurements were confirmed by direct access of experimental instruments (i.e., a thermometer) we would have no basis for pursuing a search for life in familiar form. But, while it is hard to doubt the indicated temperatures, it is less certain where they occur. Most of the moisture on the planet will be found in its higher atmosphere, where more moderate temperatures may also prevail. Perhaps, then, the place to look for any life on Venus is not on its searing surface but in the clouds; in any case we must know much more about Venus's upper atmosphere before we start taxing its real estate. It is true, by way of analogy, that our own atmosphere bears a surprising amount of life—the birds and insects and, more pertinently, a wide variety of vegetable and microbial spores—though we doubt that any forms live out their full cycles in the air.

**M**ARS, being somewhat farther from the sun, may have a temperature regime slightly chillier than Earth's, but it might likewise have retained a larger fraction of water and other important volatile material. On the other hand, Mars has only about a tenth of Earth's gravity and has been able to retain only a thin atmosphere, most of the lighter gases already having escaped. What remains might be compared to our own atmosphere at a height of at least 40,000 feet. This is far too thin for human breath but enough to give the planet a turbulent weather, judging from the massive dust storms which have been seen through our telescopes. We still know relatively little of the chemical

composition of this thin atmosphere. Of the 50-million-odd miles to the planet, the first 50 miles—Earth's atmosphere above the telescope—give us the most trouble. The only gas of which we have any definite knowledge in the Mars atmosphere is carbon dioxide; it is generally inferred that there is very little, if any, oxygen or water vapor, and that nitrogen makes up the main bulk of the gas. As a place for human habitation, even exploration, Mars would be considerably less congenial to human access and modification than the bottom of our oceans. But it is the abundance of water that must dominate our evaluation of the planet as a home for adaptable forms of life.

What then of water? Spectrograms have given direct evidence of only traces of it in the Mars atmosphere, and we cannot find seas of liquid water on the surface, but the frost is there to see as polar caps which wax and wane during the local winter and summer. The details of this weather circulation, how much water may be trapped in the soil of the temperate zones, are the key to the Martian mystery. Many astronomers have commented on the changing extent and color of dark patches that appear in these zones and particularly behind the receding polar caps in spring. These observations, reminiscent of a vegetation cycle, have been bolstered by Sinton's spectroscopic measurements through the Palomar telescope; the infrared color of the dark

Humans probably do not exist on any planet other than Earth, but somewhere in the vastness of the solar system there must be a key to the beginning of all life. Large numbers indicate distance from the sun in millions of miles; small numbers, diameter in Earth diameters.



patches corresponds to that of a layer of organic material. But this still leaves some doubts. Carbonaceous colors could mean life, but could also come from some inanimate process. Dollfus has seen the granularity of the Mars surface change with the seasons, also just as if this were the growth and decay of small plants. Taken together, these studies give little encouragement for the development of a Martian life as rich as Earth's, but they do not rule out a marginal biology whose urgent need is the finding and retention of water.

**J**UPITER, a formidable 483 million miles from the sun, is a cold planet. Its chemistry is altogether unlike that of the group of rocky planets we have just discussed—the earth and its neighbors have only the dregs of the volatile material which comprises most of the universe, most of this having been distilled off by the sun's energy. Jupiter is immensely larger than Earth, but its specific gravity is very low and it must be composed mainly of condensed liquors and ices of compounds of hydrogen, oxygen, carbon, and nitrogen. These substances are the very raw material of the evolution of life, on the one hand, and of the evolution of the universe, on the other.

It will take some presumption to plan the direct approach to this huge and mysterious planet. Its gravity, three times that of Earth, must be resisted by the landing vehicle. The low density of the surface material will call for bulky, buoyant structures. The depth of the atmosphere and the violence of its electrical storms (already heard in our radio receivers) will complicate the task of communication which distance already makes difficult.

The moon, Venus, Mars, and Jupiter—these

make up Earth's "front yard" in the solar system (with human arrogance or humor, we call this neighborhood "outer space"). Of these globes Mars presents the highest probability of sustaining forms of life comparable in any way to those we recognize on Earth, and it is therefore the primary target of our research in exobiology.

For the near future, the exobiologist or his agent cannot lift his own fragile, demanding body very far from home. But unmanned vehicles have three important purposes: They can lift telescopes into orbit past the murkiness of our atmosphere; they can carry instruments to the planets for radio communication back to Earth; they might bring back samples for detailed study in our own laboratories, although it may take another decade to build the staged rockets needed to return even a minute sample from Mars.

Moving a telescope outside our atmosphere gives larger advantages than might be supposed for a journey of only a few hundred miles. Different gases, oxygen, carbon dioxide, water vapor, which are so important in the analysis of planetary atmospheres for signs of earthly life, have characteristic colors in ultraviolet and infrared light; these are largely confused by the Earth gases through which our present telescopes must look. A vantage point in space would also improve the performance of the telescope in observing small details which are now obscured by the shimmering of our air.

**T**HE INTEREST of the exobiology research laboratory at Stanford is focused on the detection of life by means of radio signals to be returned from an instrument packet landed on Mars. Given our exquisite ignorance of the



**J**OSHUA LEDERBERG is a man of many minds—all creative. His pioneering studies in the sexual recombination of bacterial cells won him the Nobel Prize in 1958. Lately he has branched into another field. For this one he has coined the name "euphenics." It foresees the control of human development through discoveries recently made or anticipated in molecular biology. Between the two he launched exobiology, and in it he finds a common strand for all of his work—and, in fact, for all of biology and medicine—because the discovery of life on other planets would provide a fresh, unique approach to contemporary theory on the origin of all life.

Born in Montclair, New Jersey, in 1925,

the son of a rabbi, Joshua Lederberg graduated from Columbia at 19. After two years as a medical student, he shifted to biology and obtained his Ph.D. a year later at Yale under the future Nobelist, Edward Lawrie Tatum. He and another Tatum assistant, Esther M. Zimmer, were married in 1946 and they continue as research partners. He is a stimulating conversationalist, interested in music, books, and his garden.

Dr. Lederberg taught 12 years at Wisconsin before coming to the Stanford School of Medicine in 1959. He is head of the Department of Genetics and director of the Lt. Joseph P. Kennedy, Jr. Laboratories for Molecular Medicine. He is a member of the National Academy.

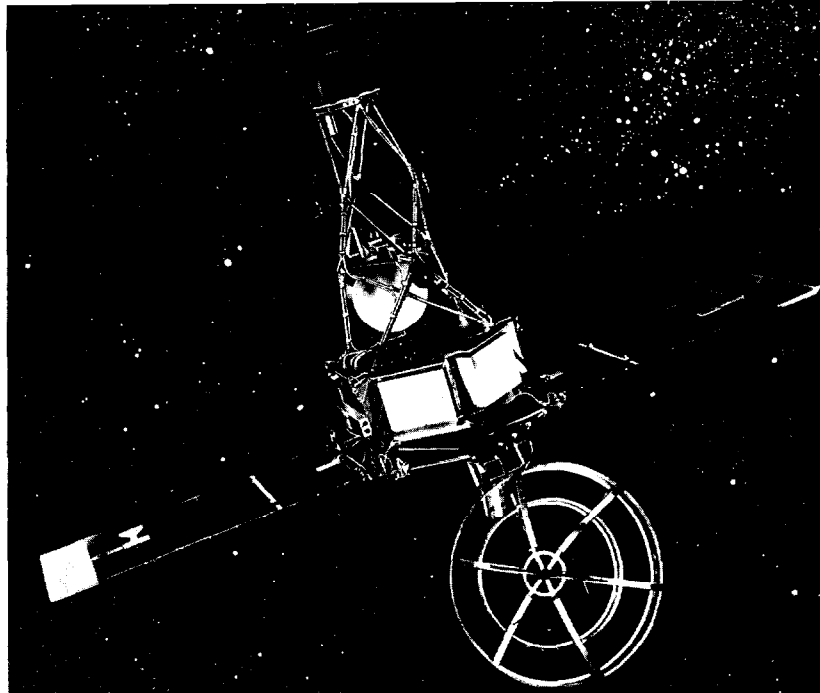


territory, how do we know what to look for and what tests and questions to build into our apparatus? The answer is that we don't, really; but this uncertainty provokes humility, not paralysis. In the first place, with the weight limitations in rocket payloads leaving us little room to mount a trap for bear, we shall content ourselves with examining a pinch of dust for microorganisms. Presumably we shall find them, if there is any life at all on Mars. At least, microbes are found everywhere on Earth—truly in all the air, waters, and soil.

What information shall we seek? We want to know if life on Mars has evolved in the same fashion as our own, how fast has it evolved, at what point might it have diverged from our pattern. We can predict with almost absolute certainty that Mars has achieved the chemogenic stage. Simple laws of physics and chemistry tell us that the presence of certain aggregates of atoms indicate there must be carbon on Mars. This is an *a priori* statement we can make without benefit of spectroscopic observation. We cannot know if the biogenic stage has been reached. As a matter of fact, we don't have a clear enough picture of terrestrial evolution to say that the earth moved from chemogeny to biogeny two billion years ago, or a half billion years earlier or later. And, of course, we cannot be sure that Martian life has not moved into cognogeny. Again, it is very difficult to predict how long it would take for a biogenic system to mature its information-handling capabilities into a cognogenic existence. We cannot discount this point; we have to include in our investigations not only inquiries as to whether or not intelligent life exists on Mars, but also whether or not it has been and gone.

Within this framework we can pose a series of rather explicit questions. We have converted a bewildering multidimensional state of possibilities into a reasonably linear array along which we can step up or down to find reasonable probabilities.

In our laboratory we are placing special emphasis on the detection of nucleic acids and proteins—the very complex molecules which are present in all forms of terrestrial life. We believe that the most important aspect of the study of extraterrestrial life is the possibility of learning in how many different ways life can evolve. Whether or not forms of life could be based on



The Mariner II gathered valuable data in a Venus fly-by mission in December 1962. (California Institute of Technology—Jet Propulsion Laboratory photograph)

substances other than nucleic acids or proteins or on related analogues of these substances is one of the most fundamental challenges to biological theory.

I WOULD only add, in conclusion, that it would be difficult to point to any practical fruits of our research—the sooner or later return of dollars and cents or gadgetry—although I think there will be some. As science becomes technically more complex and expensive, it must depend increasingly on the generosity of society. It would be tragic for both if obvious yield dominated the scientific quest; this would stultify science and would provide answers only to the problems that are already half-solved for our knowing how to ask the questions.

Expeditions beyond the earth may be among the most costly experiments so far undertaken, but they should warrant their cost as one of the very aims of the human adventure. Dante wrote of how Ulysses exhorted his companions to join his heroic journey on the great ocean: “Remember the seeds of your being: You were not made to live like beasts but to seek the fulfillment of virtue and understanding.”<sup>\*</sup> This spirit of the first explorer of the western tradition moves us today.

<sup>\*</sup> This unforgettable passage (*Inferno*, 26)—“Considerate la vostra semenza: Fatti non foste a viver come bruti ma per seguir virtute e conoscenza”—is not well rendered in English.